K-STATE
Research and Extension

Integrated Pigweed Management

Department of Agronomy | MF3448 | Weed Control

This publication helps develop an integrated strategy to manage pigweed in summer crops and fallow. Use this guide with local expertise to tailor an integrated strategy for each field. When developing an integrated weed management strategy, it is important to have an understanding of pigweed biology.

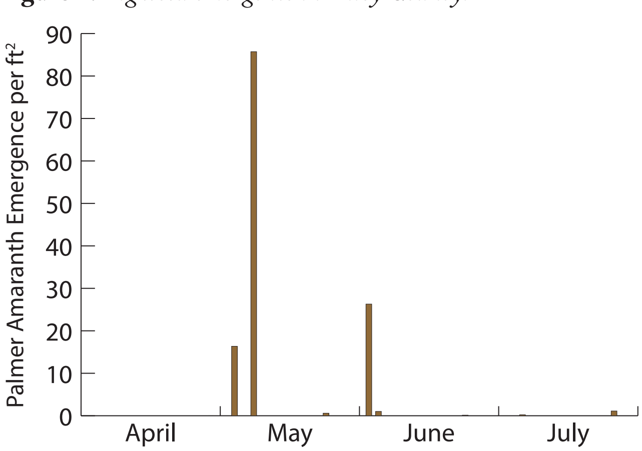
Palmer Amaranth and Waterhemp Biology

Pigweed is a summer annual broadleaf that emerges from April through October in Kansas with the majority emerging in May and June. It is common for the bulk of the emergence to occur with several large flushes during this time (Figure 1). Although there are numerous pigweed species, this publication focuses on Palmer amaranth and waterhemp. Pigweed is native to the United States. Palmer amaranth originated in the desert southwest. Pigweed thrives under warm conditions with an optimal temperature growth range of 96 to 120 degrees Fahrenheit.

Pigweed can cause drastic yield losses and harvesting difficulties in summer crops. Controlling emerged pigweed can be challenging due to its rapid growth rate, which can easily exceed 1 inch in height per day. Pigweed is a prolific seed producer with large plants capable of producing nearly one million seeds.

Palmer amaranth and waterhemp must cross pollinate because they have separate male and female plants. Because of this, each seed could have a unique genetic make-up. Pigweed produces an extremely small seed, and successful emergence can only be accomplished when the seed is near the soil surface. The viability of pigweed seed decreases rapidly when left on the soil surface or incorporated up to 6-inches deep; however, approximately 5 percent of the seed may still be viable after 3 years, which could easily replenish the seed bank if left uncontrolled (Figure 2).

Figure 1. *Pigweed emergence in Riley County.*



Herbicide Resistance

Herbicide resistance is the inherited ability of a plant to survive and reproduce after an herbicide application that would have controlled previous generations. A common misconception is that herbicide resistance is caused by the herbicides; however, herbicides do not cause genetic mutations. In fact, herbicide-resistant weeds have been found from seed that was harvested in the early 1900s – decades before herbicides were introduced. Herbicide-resistant mutants are extremely rare: a field of herbicide-resistant pigweed could have started with just one individual that contained a gene enabling its resistance to a given herbicide. Through repeated applications of the same herbicide, it is possible to select for an entire population of pigweed resistant to the given herbicide (Figure 3).

Herbicide resistance is common in many of pigweed populations (Table 1). Most herbicide resistance genes are pollen transferred which allows the herbicide resistance genes to be transferred from resistant male plants through wind-borne pollen to susceptible female plants. Research has documented that Palmer amaranth pollen can travel at least 1,000

Figure 2. *Palmer amaranth seed viability over time. Adapted from Korres et al. 2018.*

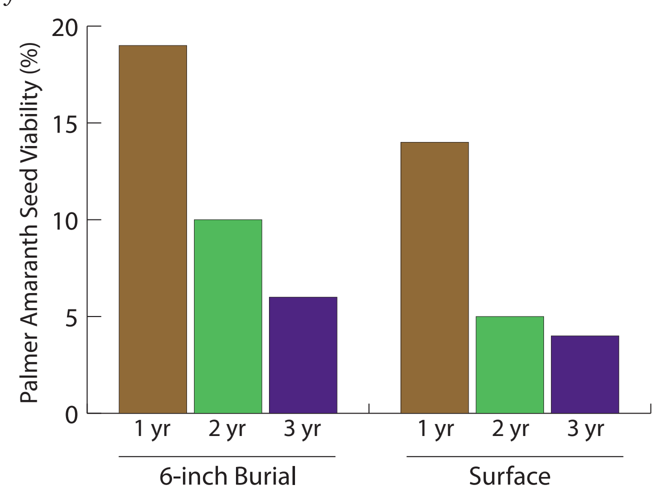


Table 1. *Herbicide resistance in pigweed in Kansas.*

Herbicide or Site of Action	PRE	POST
ALS-inhibitors	X	X
Atrazine	X	X
Glyphosate		X
PPO-inhibitors		X
HPPD-inhibitors		X
2,4-D		X

feet. The presence of herbicide resistance in pigweed in different fields varies; therefore, it is important to understand which combination of herbicide resistances are present in your pigweed population. While Table 1 lists all identified cases of herbicide resistant pigweed in Kansas, it is unlikely that a single field contains all of them. It can be easy to mistake poor control from improper herbicide application for herbicide resistance; this can be detrimental when developing an herbicide program because you may unnecessarily eliminate good herbicides from the selection portfolio (Figure 4).

Herbicide resistance is generally associated within a family of herbicides; however, the same gene(s) could enable cross herbicide resistance to multiple families within a site of action or across herbicide sites of action. Herbicide resistance genes may also be "stacked" through cross pollination to enable the spread of the resistance to other populations. While glyphosate resistance often gains the most attention, it is important to note that no herbicide is exempt from herbicide resistance in pigweed: through enough selection pressure, it is possible develop resistance to all foliar and/or residual herbicides.

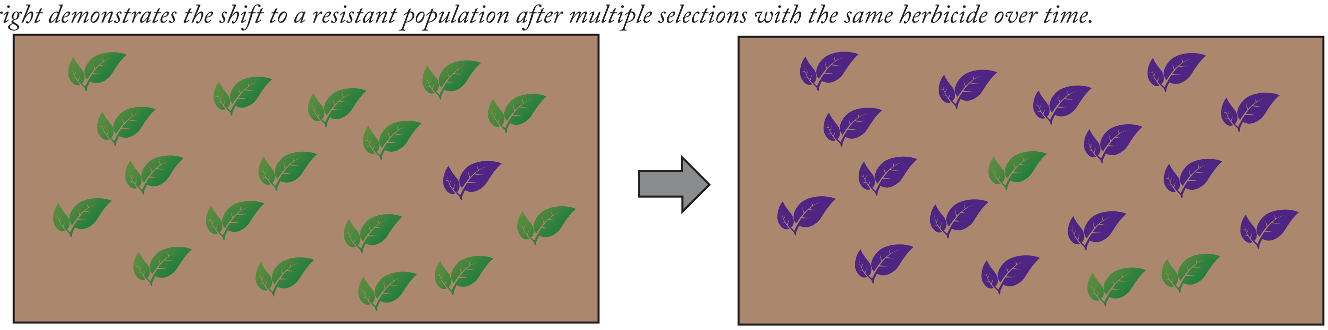
What is Integrated Pigweed Management?

An integrated approach combines many different control tactics such as crop rotation, herbicides, tillage, and row spacing to manage pigweeds in a cropping system and has three main purposes.

Figure 4. *Herbicide resistance myths.*

1. ***Regrowth after paraquat application*** (picture above). The poor control was not because of resistance but actually poor coverage from spraying too large of pigweed.
2. ***Drought stress.*** When weeds are stressed, herbicide performance decreases because of reduced herbicide absorption or translocation, not herbicide resistance.
3. ***High or low soil pH.*** While pH can influence the performance of residual herbicides, it does not cause mutations to enable the herbicide resistance genes.
4. ***Poor application procedures.*** Inadequate application procedures can result in less herbicide reaching the target site; however, this does not result in resistance. Resistance selection occurs through multiple generations; an individual weed cannot be "conditioned" into becoming resistant through low doses.
5. ***Dust on the leaves.*** Dust on leaf surfaces limits absorption of an herbicide; however, the progeny of the dust-covered weed will be no more resistant than prior generations to the herbicide of choice.

Figure 3. *A representation of pigweed in a field with the purple specimen as naturally herbicide-resistant individual. The figure at right demonstrates the shift to a resistant population after multiple selections with the same herbicide over time.*



1. Decrease the risk of selecting for resistant biotypes to an herbicide or other management practice.
2. Reduce pigweed seed production.
3. Increase long-term profitability and sustainability.

With enough selection pressure, it is possible to select for pigweed that is resistant to cultural or mechanical practices. For example, shifting crop planting date earlier may select for a biotype that emerges later in the season after POST herbicides are applied, or by implementing sequential tillage operations in fallow, a shift towards alternative seed dormancy mechanisms could occur. With an integrated approach, it is less likely for these types of shifts to occur because the selection pressure is shared among various tactics.

When developing an integrated pigweed management plan, consideration should first be given to cultural control tactics. It is not always possible or applicable to implement all strategies in certain systems; therefore, consideration must be given to how each tactic fits in combination with the other goals of the cropping system (Figure 5).

Crop Rotation

Crop rotation can reduce pigweed seed production and suppress pigweed growth. Crop rotation can be successful in pigweed management if the rotation enables the use of a new management tactic (i.e., a more effective herbicide, tillage, or competitive crop) or with the introduction of winter crops (i.e, wheat or canola) or perennial crops (i.e., alfalfa). Crop rotations that use multiple summer annual crops that employ similar control tactics (i.e., glyphosate-resistant corn and glyphosate-resistant soybean) result in limited benefit compared to more diverse and intensive crop rotations. Crop rotations should be evaluated for weaknesses such as excessive pigweed seed production after harvest or during fallow periods. Slight adjustments to a crop rotation might enable the use of other cultural strategies such as a cover crop.

Crop Cultivar Selection and Planting Date

When possible, select crop cultivars better adapted to shade the ground and provide canopy closure. Examples include bushy-type soybean varieties or sorghum hybrids more apt to tiller. This may not always be practical as the primary consideration for cultivar selection should always be placed on yield optimization.

Selecting herbicide-resistant crops offers the use of an herbicide that was otherwise not available. Numerous crops contain resistance to multiple herbicides (i.e., Enlist Cotton, Enlist Soybean, and Xtendflex Cotton). Future herbicide-resistant crops will continue with this trend by adding multiple herbicide-resistant traits into the same varieties or hybrids. While this could increase selection pressure on specific herbicides if used continuously in each crop, it also provides the option to use more effective sites of action in tank mix, which can reduce the risk of herbicide resistance (see more in herbicide section).

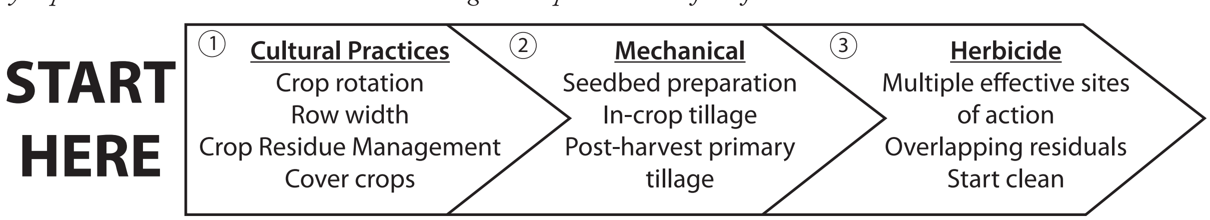
Planting date has an important role in weed management and should be based on pigweed emergence by shifting the critical weed-free period (i.e., early season developmental stages) to occur outside of maximum pigweed emergence. A delayed planting date could enable initial flushes of pigweed to be controlled with a burndown herbicide or tillage before planting. While planting date considerations can be part of a pigweed management plan, primary emphasis should be placed on selecting a planting date that is optimal for yield.

Cover Crop

Cover crops can limit the germination and suppress the growth of pigweed. By reducing pigweed emergence, the selection pressure on herbicides is less. Cover crops also can suppress pigweed growth and limit weed seed production.

Cover crops suppress pigweed through physical interference (light interception, and changes in soil moisture and temperature) with the aboveground biomass. Research at K-State has demonstrated that a winter wheat cover crop can result in approximately a

Figure 5. *When developing an integrated pigweed management strategy, cultural practices should be considered first. Too often, it is easy to place all consideration on herbicide and neglect the potential benefits of cultural and mechanical tactics.*



50 percent reduction in early-season pigweed density (Figure 6). When managing a cover crop to suppress pigweed, strategies that produce ample biomass should be implemented: selection of a species (i.e., winter wheat, triticale, cereal rye), seeding date and rate for fall growth, fertility management, and termination date influence cover crop performance. If any of these factors is neglected, less than desirable biomass and subsequently less weed suppression may result. Additional consideration at planting of the cash crop in terms of cover crop residue management and fertility placement may be required.

Narrow Row Spacing

The use of narrow row spacing (less than 30-inches) has the potential to suppress pigweed growth. Dryland research at K-State has revealed that it may be difficult to achieve direct benefits from narrow row spacing in soybean and grain sorghum in regard to pigweed control. When row spacings were compared within the presence or absence of a winter wheat cover crop, no differences in pigweed density were observed other than those benefits offered by the cover crop (Figure 6). When data were pooled, a 30 to 35 percent reduction in late season pigweed biomass was observed as row spacing was decreased (Figure 7).

While narrow rows could reduce pigweed seed production, narrow rows did not reduce the selection pressure on herbicides. Early-season weed management in wide and narrow row spacing will not change because light interception with the crop is similar across all row spacings.

Field Border Management, Seed Transfer, and Zero-Tolerance Policy

An integrated pigweed management program can become expensive; however, several low-cost tactics are seldom implemented. One overlooked tactic is field border management. It is common to see field borders overrun with pigweed in the late summer. These serve as a seed production area for pigweed to encroach into the field through mechanical and animal transfer. The weediest areas of the field are often near the field borders because of this problem. Several management strategies exist such as using an ATV to treat the field borders with herbicide, mowing, or establishing aggressive perennial grasses to suppress the pigweed.

Because of the small size of pigweed seeds, it is easy for pigweed to be unknowingly transferred with the combine. Cleaning procedures should be implemented if equipment, especially the combine, is operated in fields containing a high population of pigweed before moving to fields with lower densities. A few hours with a pressure washer could drastically limit the spread of herbicide resistant individuals (Figure 8).

The resiliency of pigweed is through robust seed production. After a pigweed returns to the seed bank, it is possible for it to remain viable for more than 3 years

Figure 7. *Late-season pigweed biomass in dryland soybean and grain sorghum as a percent of the plot average across 11 site years.*

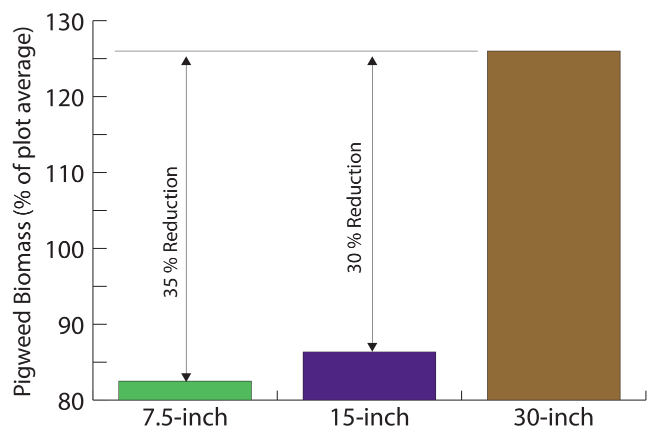
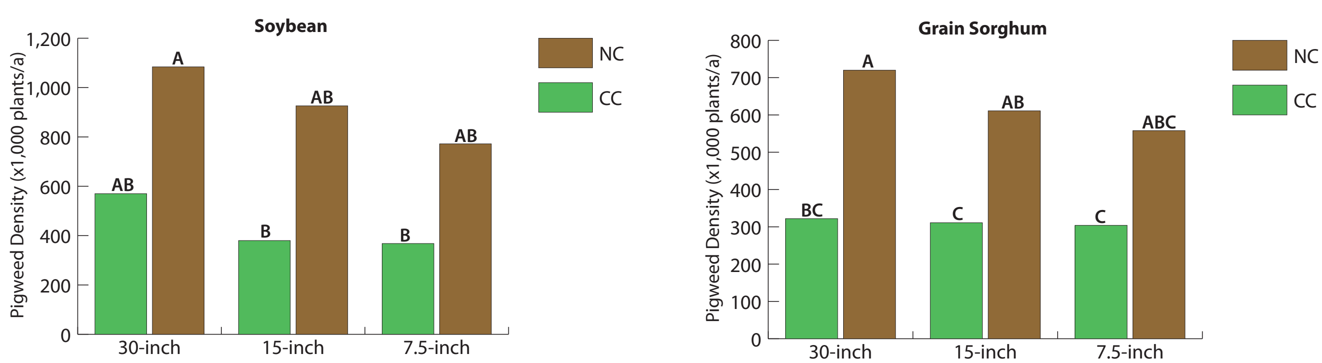


Figure 6. *The influence of row spacing and winter wheat cover crop on early-season pigweed density in Riley (left) and Reno (right) counties.*



Treatments with the same letters within a graph are not different. CC = winter wheat cover crop; NC = no cover crop. Winter wheat cover crop terminated 2 weeks before planting.

Figure 8. *A grain drill was operated in a field with a high pigweed population. Upon closer inspection, the wheels of the drill were covered with pigweed seed (small black spots in picture at right). To prevent seed transfer, the drill should be cleaned.*

(Figure 2). Because of this, a robust integrated strategy is a zero-tolerance approach for pigweed seed production. Fields where there may be just a few escapes in end rows are excellent candidates for the zero-tolerance policy. Just a few hours a week of hand hoeing substantially reduces the number of seed returning to the seed bank. Another important application of the zero-tolerance approach is in postharvest weed management. Pigweed that emerge within 30 days of a killing frost can produce seed. In crops with an early harvest such as field corn, postharvest management to limit seed production is warranted.

Mechanical Control

The use of mechanical control tactics such as tillage for pigweed management can be classified in one of three ways.

1. Bury pigweed seed to inhibit its emergence
2. Stimulate emergence for seed bank depletion or to create a false seed bed
3. Destroy emerged pigweed

The use of tillage is controversial in Kansas because of soil and moisture conservation purposes; however, tillage can offer value as part of a system for integrated pigweed control. A single-time moldboard plowing is the most effective primary tillage option to bury pigweed seed (DeVore et al. 2013); however, annual moldboard plowing has the potential to cycle pigweed seed back to the soil surface. Conservation tillage options (i.e., chisel plow) have been demonstrated to offer reductions in pigweed density but not to the level achieved with the moldboard plow. When moldboard plowing, conservation tillage, and no-tillage were compared, the poorest pigweed control was observed in no-tillage (Leon and Owen 2006).

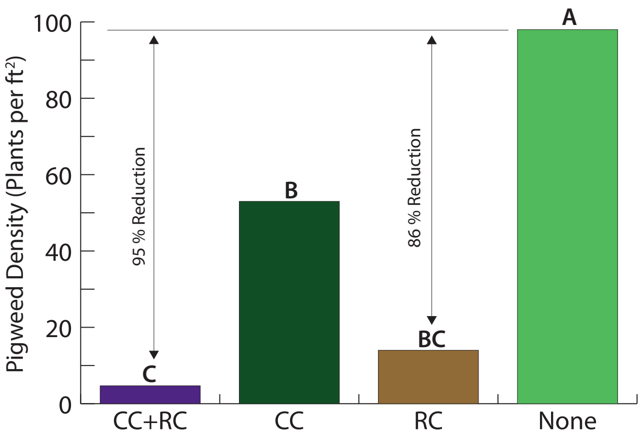
Secondary tillage such as a field cultivator can be used to stimulate pigweed emergence to create a false seed bed before planting summer annual crops. Because the tillage stirred and warmed soil, pigweed emergence will be stimulated and can be controlled with additional tillage or a burndown herbicide before the crop emerges. Additionally, repeated use of tillage can be used to help exhaust the soil seed bank such as in a fallow period. While it is almost impossible to eliminate pigweed from the soil seedbank, this methodology can reduce seed bank levels.

By using tillage to destroy emerged pigweed, the selection pressure on subsequent herbicides is reduced and therefore, reduces the risk of herbicide resistance. Tillage tools such as a disk, field cultivator, or V-blade sweep plow can do a fair job of controlling weeds in a fallow or preplant situation and can do excellent job when used in combination with a planned herbicide program. Timely row-crop cultivation can be effective at controlling pigweed between rows (Figure 9). Row-crop cultivation should be used as a planned application 2 to 3 weeks after planting to control small weeds instead of as a rescue treatment.

Building an Integrated Strategy

Combining control tactics yields the best results. When developing these recommendations, have realistic expectations and make considerations from a cropping systems point of view. It can be difficult to see direct economic profit from some cultural practices such as narrow row spacing, cover crops, or crop rotation; however, long-term gain will be realized through delaying the onset of herbicide resistance and reduced weed seed production.

Figure 9. *Pigweed control 21 days after planting as influenced by cover crop and row-crop cultivation in soybean.*



CC = winter wheat cover crop
RC = row-crop cultivation.
Bars with the same letter are not statistically different. The cover crop was terminated 2 weeks before soybean planting; row-crop cultivation implemented 18 days after planting.

Developing Herbicide Recommendations

A common pitfall when trying to justify the cost of integrated strategies is through a reduction in herbicide use. This concept is not supported with research, and all integrated strategies still must be combined with a comprehensive herbicide program. Research shows herbicide programs targeting pigweed must have three key components (Figure 10).

MESA in Tank Mix and Rotation

The use of multiple effective sites of action (MESA) in both foliar and residual herbicide applications has been demonstrated as an effective way to increase pigweed control and delay herbicide resistance. When building an herbicide plan, it is imperative to understand which sites of action are effective on each pigweed population, and then purchase herbicides accordingly to achieve MESA. Many premixes are available that contain numerous sites of action; however, no real resistance management benefit has been realized unless they are *effective* on the given pigweed population. For example, if dicamba and glyphosate were applied as a tank mix to a pigweed that is glyphosate resistant, essentially there is one effective site of action in the tank (dicamba). This will eventually select for herbicide resistance to dicamba in addition to glyphosate resistance. When developing an herbicide program for pigweed, special effort should be placed on using herbicides with excellent efficacy (Table 2).

Start Clean with No Pigweeds

The most yield will be lost when pigweed emerges before or with the crop. After the crops's emergence, the herbicide options available for POST control in crops are limited. Before the crop's planting, it may be possible to eliminate emerged pigweed with secondary tillage or a burndown herbicide. In addition to preserving crop yield, starting clean can also reduce the selection pressure placed on PRE or POST herbicides. Depending on planting date, up to 50 percent of the pigweed population may have emerged before planting (Figure 1).

Overlapping Residuals

The goal of an overlapping residual herbicide program is to limit the number of pigweeds that must be controlled with foliar herbicides and is built around two key components of 1) achieving initial residual herbicide activation and 2) ensuring herbicide activity through crop canopy. The standard recommendation is to use a PRE (residual) herbicide at planting; however, in some situations, this is not adequate when activating rainfall (generally greater than 0.75-inches) is not received (Figure 11). In these situations, a difficult-to-implement early POST application is required. Consider if an overlapping residual program were used; the full rate of residual herbicide in the PRE treatment was split between a pre-plant followed by PRE program in which half to two-thirds of the residual was applied 2 weeks before planting to increase the chances of activation, and the remainder was applied at planting. With this program, the risk of failure is reduced. (Figure 11).

The second component involves reapplication to ensure control until canopy formation. Most residual herbicides provided adequate control for 28 days after application if activated. Crop canopy is generally achieved 8 to 12 weeks after planting. In some crops with low seeding rates, such as dryland corn, canopy may never be achieved. If the crop is experiencing delayed canopy due to stress or low seeding rate, a sequential POST residual application may be warranted.

Figure 10. *There are three key components that should be found in every pigweed herbicide program.*

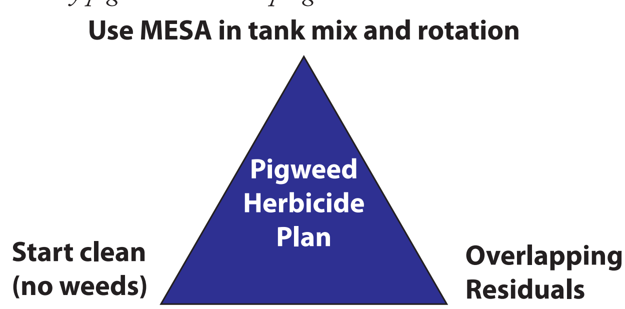


Table 2. *Commonly used herbicides and their efficacy on pigweed from residual and foliar applications.*

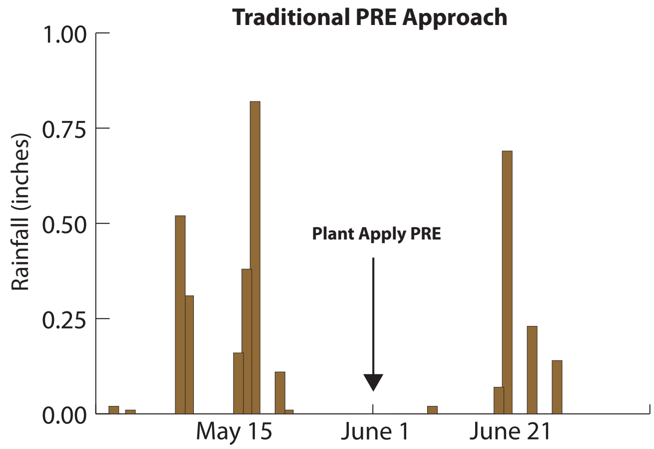
SOA (WSSA Number)	Herbicide	Trade Name	Residual	Foliar
†ALS Inhibitors (2)	imazaquin/imazethapyr	Scepter/Pursuit	E	E
	imazamox	Raptor/Beyond	G	E
	chlorimuron	Classic	F	F
	chlorsulfuron	Glean	E	E
	metsulfuron	Ally	E	E
	thifensulfuron	Harmony	-	G
	chloransulam	FirstRate	P	-
	flumetsulam	Python	F	F
Microtubule Inhibitors (3)	pendimethalin	Prowl	F	-
‡ Growth Regulators (4)	dicamba	Clarity	P	G
	2,4-D	Enlist One	-	F
	clopyralid	Stinger	-	-
	halauxifen	Elevore	-	-
	fluroxypyr	Starane	-	-
	quinclorac	Facet	-	-
Photosystem II Inhibitors (5-7)	†atrazine	Aatrex	E	E
	metribuzin	Sencor	E	E
	bromoxynil	Buctril	-	P
	diuron	Direx	E	E
	linuron	Lorox	F	E
‡EPSPS Inhibitor (9)	glyphosate	Roundup	-	E
Glutamine Synthetase Inhibitor (10)	glufosinate	Liberty	-	E
‡PPO Inhibitors (14)	carfentrazone	Aim	-	P
	fluthiacet	Cadet	-	P
	flumiclorac	Resource	-	P
	lactofen	Cobra	-	G
	acifluorfen	Ultra Blazer	-	G
	fomesafen	Flexstar	E	G
	flumioxazin	Valor	E	G
	sulfentrazone	Spartan	E	P
	saflufenacil	Sharpen (1 oz/a)	P	E
	saflufenacil	Sharpen (> 2 oz/a)	E	E
VLCFA Inhibitors (15)	S-metolachlor	Dual Magnum	E	-
	metolachlor	Dual	G	-
	dimethenamid-P	Outlook	G	-
	acetochlor	Warrant	G	-
	acetochlor	Harness	E	-
	pyroxasulfone	Zidua	E	-
Photosystem I Electron Diverter (22)	paraquat	Gramoxone	-	E
‡HPPD Inhibitors (27)	isoxaflutole	Balance	E	P
	mesotrione	Callisto	E	E
	topramezone	Armezon	-	E
	tembotrione	Laudis	-	E

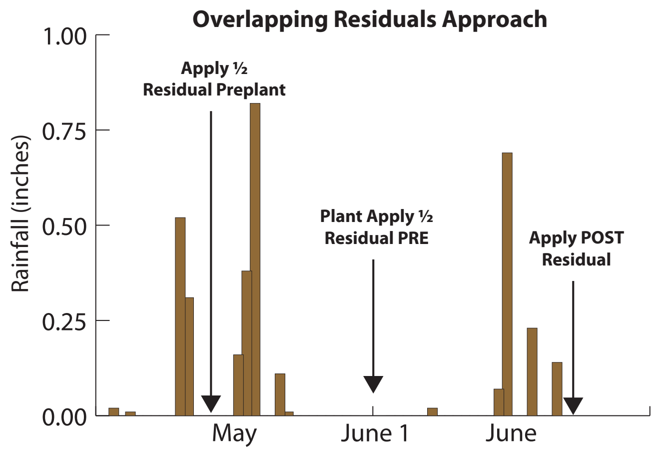
† Resistant biotypes have been confirmed to both residual and foliar activity of these herbicides.

‡ Resistant biotypes have been confirmed to only foliar activity of these herbicides.

E = excellent, G = Good, F = fair, P = poor, (-) not labeled.

Figure 11. *The top graph and picture at right illustrate how a PRE, without activation, results in poor control at Hutchinson, Kansas. The lower graph illustrates how overlapping residuals might have been used to achieve better results.*





3.5 ounces per acre Fierce applied PRE on June 1 (photo taken June 21). Note lack of contribution from 15-inch row spacing in the soybean.

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